Cost efficient 3d printed lens mounting, an alternative for prototyping

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We proof the capabilities of simple FDM 3d printing for lens mounting applications and thus, a quick prototyping tool. The goal is to reduce time and costs, especially for small companies. This was achieved by using a Prusa MK3S printer and the Cura slicing software, as well as a test triplet designed in OSLO using of the shelf lenses.

1 Introduction

We show an approach how to reduce time and cost for prototyping simple optical systems. With most common rail systems you need a large assortment of parts to cover various applications. The needed space can make it difficult to place modules built with rail system components within a machine or system.
While 3d printing becoming cheaper and better every year, we tried to take advantage of this type of manufacturing to build fast and cost efficient lens mountings. The flexibility of printing mounts in the appropriate size and dimension, as well as including counter parts for easy installation, are the advantages of this method. Due to the tolerances the described method is limited to low end optics.
Depending to the needed tolerances, required by the specified application, it is quite possible to use printed mounts for small lot size commercial optics.

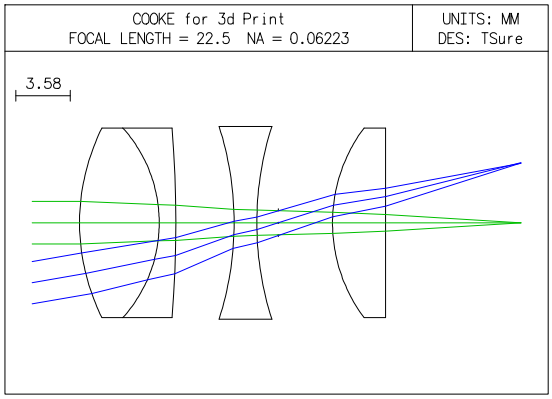

Fig. 1 *Cooke triplet designed with* OSLO. *Print orientation for the mount, left lens is bottom and the right lens is top.*

2 Preparation

Before starting to print the entire system, it is essential to evaluate the printers tolerances, capabilities and design aspects of the mounts. This included various test prints with different dimensions for the lens mount, material choice, and print setting optimization, as well as temperature stress tests and long term observation which were done during a bachelor thesis [1]. The mounts were also checked on long term behavior and thus stress tested with temperature shifts, shock tests and simple over time behavior.
We found that PETG is the preferred material. For future use ASA, ABS and PA are also great candidates to tests.
For the first optical system a Cooke triplet, see Fig. 1, designed with of the shelf components, will be used.

3 Mount concept

General concept is to print the mount up to the upper edge of a lens (see Fig. 1, right lens faces), pause the print to place the lens and continue the print. For this example, also the aperture stop is a printed diaphragm.

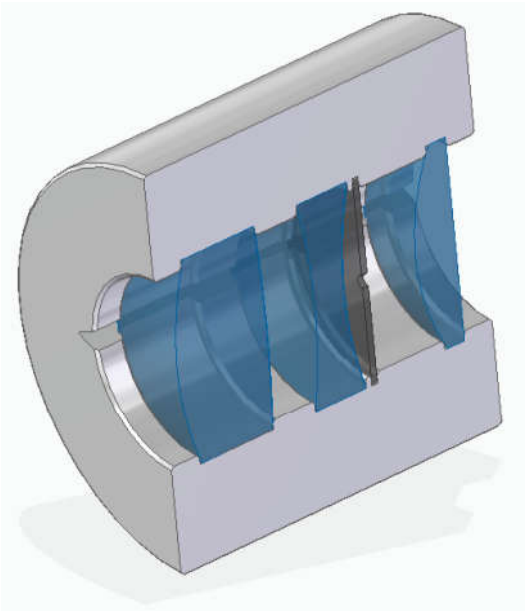

Fig. 2 *A split model of the CAD design. Notice the V-groove along the axis, this is explained in the print settings.*

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Due to cooling of the material after the print is finished, shrinkage of the plastic ensures a tight fit of the lenses.
For the axial alignment of the lenses the layer height of the printer is a key parameter. The layer height slices the model into several layers, so reference surfaces for the lenses are incremental. The relevant surface is the lower surface on which the lens is placed. For convex lens surfaces, the diameter of the reference surface adjusts the position of the lens and can be set to fit the layer increments. The upper lens surface is fixed down by material placed on top of the lens. This can also cover a small gap and ensures a tight fit.

4 Print settings

Printing the mount was done on a Prusa i3 MK3S [2] firmware version 3.6.0 and the G-code was generated by Cura [3] version 4.4.0. Three essential settings must be considered.

4.1 Z-Hop

Z-Hop is a feature that influences the movement of the nozzle of the printer. Every time the printer stops and needs to start extruding at a new point it directly moves to the next location. With Z-Hop enabled the nozzle is lifted by a determined value before moving to this location. It is crucial to avoid any collisions with the lenses. Due to the overhang of the lenses, this should always be enabled and the level must be set high enough. This is especially important when printing multiple mounts parallel.

4.2 Combing

Combing also influences the movement of the nozzle. It keeps the nozzle on free travels within the perimeter of the model. This also avoids collisions with the lenses, but mainly removes stringing (loose bits of material oozing from the nozzle while traveling, leaving thin strings). As the mount is completely enclosed, there is no way to remove strings after printing. Combing lets the nozzle move over the infill and thus, strings get caught there.

4.3 Z-Seam alignment

This feature influences the placement of start and ending points of the extrusion in each layer. Setting this to `hide seam` will position the start and end point to inner corners. For this reason, the V-groove, see Fig. 2, is added to avoid a little bump which would shift the central alignment.

5 Performance

To demonstrate the performance capability, we measured the on axis MTF of the above described system. Due to the fact that we used of the shelf lenses we limited the numerical aperture to NA = 0.063 (F-number = 8). A tolerance analysis based on the printer tolerances has been done. We assume for the variation of the layer thickness $\pm$0.075 mm and a lateral position error of the extruded material of $\pm$0.05 mm. The tolerance analysis using the above values shows that the MTF at 50 lines/mm will drop from 72% (design value) to 52.1%. Fig. 3 shows the measured MTF which confirmed the expected image performance.

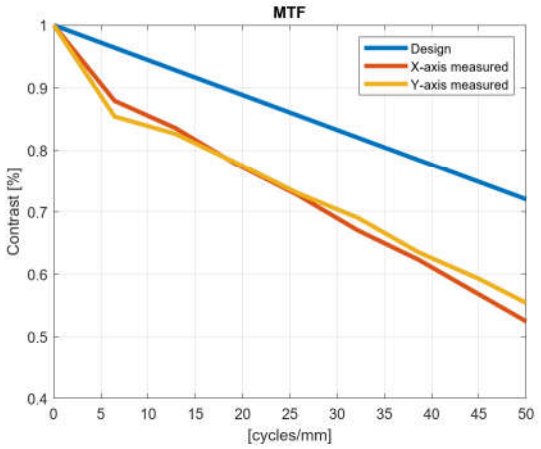

Fig. 3 *Plot of the MTF from the designed triplet and the measured MTF of the triplet in the printed mount.*

6 Conclusion

It has been demonstrated, that 3d printing could be an option to build mounts for low end optics. The image performance of the realized Cooke triplet is not too bad. The accuracy of the flow of the extruded material has the main impact onto the position errors of the lenses, which causes the drop in the MTF. Future investigations to optimize the design of the mounts and the printing process will be done.

References

[1] M. Dippel, “Untersuchungen zur Maßhaltigkeit einer 3d gedruckten Linsenfassung,” (2019). Bachelorthesis.

[2] “Prusa Research,” URL `https://www.prusa3d.de/`.

[3] “Ultimaker Cura Slicing Software,” URL `https://ultimaker.com/de/software/ultimaker-cura`.